Nationaal Lucht- en Ruimtevaartlaboratorium
National Aerospace Laboratory NLR

AMS Tracker Thermal Control Subsystem

TTCS Filling system

AMSTR-NLR-TN-019
ISSUE 2.0
NOVEMBER 2005

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FILENAME	AMSTR-NLR-TN-019_2.0FillingSystemandAccuracy.doc	ORDER-/CODENUMBER:	2494047
LAST SAVED	2005.11.16 17:58 by J. van Es	DIVISION:	AS&A
PRINTED	2005.11.16 18:15	DISTRIBUTION:	Unlimited
PAGES	13	CLASSIFICATION TITLE:	Unclassified

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An electronic version of this document is available on the AMS TTCS website:

https://ams-ttcs.nlr.nl

Document change log

Change Ref.	*Section(s)*	*Issue 1.0*
-	All	Initial issue

Change Ref.	*Section(s)*	*Issue 2.0*
-	All	Lay-out (again possible to print)
	Section 2.5.2	Updated fill rate to value consistent with 160 bar and 65 C

Summary

This document describes the preliminary design of the TTCS filling system.

Contents

(13 pages in total)

1 Scope of the document

This document describes the preliminary design of the TTCS filling system. This includes the estimations of the fill accuracy.

1.1 Reference documents

RD-1	Combined proposal Development of the Tracker Thermal Control System of the Alpha Magnetic Spectrometer, SYSU/NLR/INFN, J. van Es, B. Oving, R. van Benthem, July 2004.	NLR-ASSP-2004-021 Issue 1
RD-2	Requirements for the manufacturing and space qualification of all the pressurised weld joints in the AMS TTCS evaporator, revision B, B. Verlaat, 2 Sept. 2003	ASR-S-001
RD-3	NASA- document “Simplified Design Options for STS-Payloads”	JSC-2045RevA

2 AMS TTCS Filling System

The main requirements in filling of the TTCS system are:

1. Assure that contamination of particles is less than the required cleanliness
2. Assure that the fill accuracy is met

2.1 TTCS Loop Cleanliness

All separate components will be delivered visibly clean to NLR. For critical components (Pump, valves and accumulator) the cleanliness of the component is proven by the supplier.
The requirement is ass follows:

Metallic particles are not allowed.
The maximum number of non-metallic particles in a 100 ml sample shall be as follows and is equivalent to MIL-STD-1246 C class 100:

- > 100µm none
- 100 µm 5 max
- 50 µm 50 max
- 25 µm 200 max
- 10 µm 1200 max
- 5 µm no limit

2.2 Loop cleanliness procedure

After delivery to NLR (EM), SYSU (QM/FM) and before integration, the loop (or parts of the loop) will be cleaned.
The loop (or loop parts) go through the following procedure:

- Cleaning with IsoPropylAlcohol (IPA)
- Pumped dry (and/or heated)
- Flushed with Nitrogen and/or Carbondioxide

2.3 Loop cleanliness for filling ground support equipment

The same procedure applicable for the loop components is also applicable for the fill system (see section 2.2)

2.4 TTCS leak rate

The calculation of the leak rate can be found in the accumulator volume calculation [xx]. As the system pressure always exceeds the TTCS system the pressure the leak direction is such that no air, water vapour or non-condensable gasses will enter the loop after filling.

2.5 TTCS Fill accuracy and fill procedure

In the following the procedure to fill the TTCS system is described. The main objective is to assure the fill accuracy requirement is met. The main driving factors for the accuracy are:

- Assure a maximum design pressure of 160 bar at 65 C
- Assure liquid in the TTCS accumulator during start-up –40 C

2.5.1 Purity of CO2

The purity for CO2 used is a quality of 99.99 % pure CO_2.

2.5.2 Fill accuracy

The fill accuracy depends on:

- Accuracy of the TTCS loop volume measurement
- Accuracy of the fill mass

A more convenient way to determine the fill accuracy is to use the fill ratio. The fill ratio is:

Fill Ratio: FR = Total mass/Total Volume.

It is in fact a mean density in the loop. The accuracy of the loop fill rate is than the sum of the relative error of loop volume and the loop mass:

$dFR/FR = dm/m + dV/V$.

The following accuracies are realistic for a filling system

- $dm/m = \pm 2\%$.
- $dV/V = \pm 2\%$.

Resulting in a fill accuracy of

- $dFR/FR = \pm 2\% + \pm 2\% = \pm 4\%$.

More detailed calculations based on details of a filling system could tighten the fill accuracy
With a 4% fill accuracy a fill rate, FR = 580 g/l shall not be exceeded because it is directly related to the maximum design pressure of 160 bar. Therefore FR_{max}= 580 g/l. Filling should be done using FR = 557 g/l ±4%.

FRmaxstart	580	[g/l]	Max fill rate at start (no leak)
FR.tot	536	[g/l]	Min. Fill rate based on fill accuracy
System leak	30.80	[g]	Mass leakage during operation
FRtot,end	**516.22**	[g/l]	Min. Fill rate end of life

This results in minimum fill rate of FR_{min} = 557-4% = 536 g/l.

2.6 Fill procedure

The fill procedure consists of the following major steps:

1. Determination of the exact TTCS-loop volume
2. Filling of the TTCS-loop with the exact fill rate

It is proposed to perform the fill procedure during integration at CERN in Switzerland.
Main implication on AMS system level after the TTCS is filled, is the temperature requirement of the TTCS-system to stay below 65 °C during transportation.

2.6.1 TTCS volume determination

The first important step in the fill procedure is to determine the exact TTCS loop volume. In Figure 2-1 the measurement set-up for the volume determination is shown. The principle of volume determination is to measure the pressure of an accurately known volume (Vol 1) before and after connection with the TTCS-loop. The pressure decay gives (in)directly the TTCS loop-volume. The method will be verified and validated by tests with two accurately known volumes Vol2 and Vol3, respectively larger and smaller that the TTCS-loop volume.

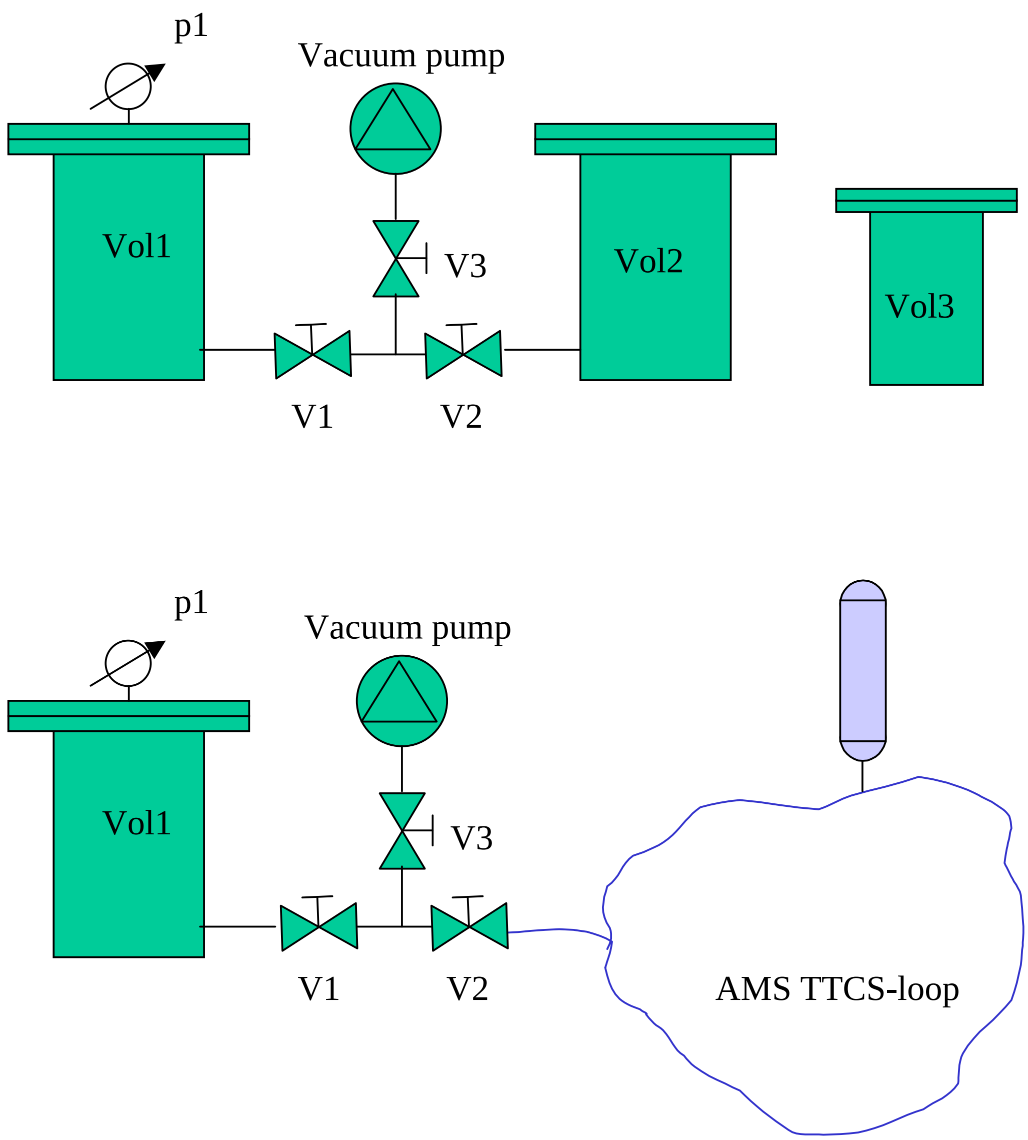

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Figure 2-1: Loop volume determination set-up

Vol2 and vol3 are test volumes with very well known dimensions

p1 is a pressure transducer

The procedure is as follows:

#	Action
1	Vacuum all volume V1
2	Fill volume Vol1 with N2 or CO2
3	Gently vent using V1 until exact pressure is detected in reservoir and close V1
4	Measure Pressure inside Vol1
5	Connect reservoir + V1 to TTCS-loop as in figure above
6	Leak test fill system and attached Vol2 or Vol3
7	Evacuate AMS TTCS loop + fill system volume (using V1,V2)
8	Close V3, open V2
9	Open V1
10	Measure pressure in total volume (Vol1 + Vol2)
11	**Repeat the above sequence with volume Vol3**
12	**Repeat the above sequence with the TTCS-loop attached**
13	**Calculate the TTCS-loop volume based on the pressure decay**

Table 2-1: Procedure to measure the TTCS-loop volume

With the accurately known TTCS-loop volume the exact fill rate can be calculated. In the next section the fill procedure with this exact amount of CO_2 is described.

2.6.2 TTCS fill system and fill procedure

In Figure 2-2 a schematic of the TTCS fill system is shown. The system consists of:

- An accurate mass balance to measure the CO2 mass
- A reservoir with a heater

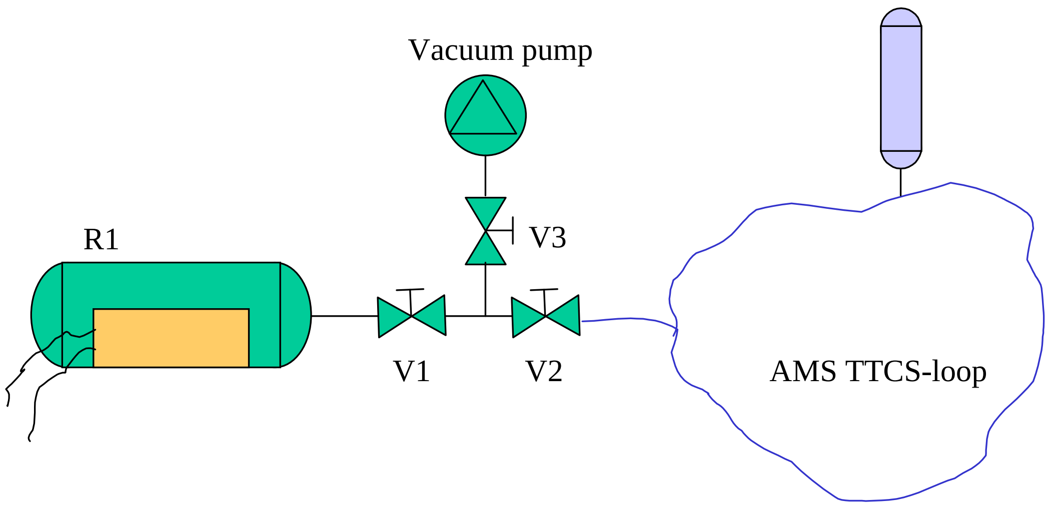

Figure 2-2: TTCS Fill system schematic

The balance is used to accurately measure the amount of CO_2 in the reservoir before filling and after filling. The reservoir is equipped with a heater to assure all CO_2 left in the reservoir is vapour.

The procedure to fill AMS TTCS with CO_2 is described in Table 2-2.

#	Action
1	Put reservoir R1 + valve V1 on balance (empty)
2	Fill reservoir R1 with excess amount of CO_2
3	Gently vent using V1 until exact amount is in reservoir and close V1
4	Connect reservoir + V1 to TTCS-loop as in figure above
5	Leak test fill system
6	Evacuate AMS TTCS loop + fill system volume (using V1,V2)
7	Close V3, open V2
8	Open V1
9	Heat R1 up to 65 °C cool loop downto 10 °C (TBC for condensation of water)
10	Close V1
11	Heat fill system volume up to 65 °C (heater not shown in Figure)
12	Close V2
13	After cool down, disconnect R1 + V1 from fill system volume
14	Put reservoir R1 + valve V1 on balance
15	Check rest weight

Table 2-2: TTCS Fill procedure

The above procedure assures the filling of the loop with pure CO_2. Possible drawback of the system is the CO_2 rest weight left in the reservoir. Some measures are foreseen to account for this.

- Test the fill system in advance to predict the rest weight.
- Optionally, the use of an (air operated) stainless steel bellow inside the reservoir R1 will further reduce the CO_2 rest weight after filling
  Remark: the use of a plunger is avoided because of the possible seal leak
- Another option is to cool the loop radiators during filling to further reduce the rest weight. Remark: This would imply integration effort to avoid condensation of water. As the TTCS is being filled when integrated in AMS this has impact on the complete AMS integration sequence.